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NATURAL ENVIRONMENT DESIGN REQUIREMENTS FOR THE SOLAR ELECTRIC PROPULSION STAGE (SEPS)

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16. ABSTRACT

Given in this report are the natural environment design requirements for the Solar Electric Propulsion Stage. Environment criteria for the SEP Stage will cover earth orbital operations out to geosynchronous altitudes and also interplanetary missions including comet and asteroid missions.

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1.0 PURPOSE AND SCOPE

The definition of antural environment design requirements for the Solar Electric Propulsion Stage (SEPS).

2.0 NATURAL ENVIRONMENT - GENERAL

The natural environment criteria given in this report are consistent with those specified for the Space Shuttle system and will be used for design of the SEPS with respect to radiation atmospheric characteristics at orbital altitudes, and other pertinent natural environment requirements. Design value requirements of natural environment parameters not specifically defined in this report will be obtained from NASA TM X-64757, "Terrestrial Environment (Climatic) Criteria Guidelines for Use in Aerospace Vehicle Development, 1973 Revision," dated July 5, 1973 [2], and NASA TM X-64627, "Space and Planetary Environment Criteria Guidelines for Use in Space Vehicle Development, 1971 Revision," dated November 15, 1972 [1], and subsequent addenda to those documents. The SEPS will be subject to environmental factors peculiar to the Space Shuttle during assembly, checkout, launch, and attainment of orbital positioning prior to removal of the SEPS from the Shuttle bay; therefore, appropriate Shuttle documents should be consulted when the SEPS is "cargo" in the Space Shuttle. The SEP Stage may be launched by a Titan IIID/Centaur combination. In this case, a shroud would be used to protect the stage from natural environmental hazards. Information given in Reference 3 should be used along with the above mentioned NASA documents when the SEP Stage is not "cargo" in the Space Shuttle.

3.0 EARTH ORBITAL ENVIRONMENT

This section provides natural environment criteria for use in studies related to the Solar Electric Propulsion Stage during earth orbital phases. Values of natural environment parameters not specifically defined below will be obtained from Reference 1.

3.1 Neutral Gas Properties

3.1.1 The Jacchia 1970 Model Atmosphere will be used. See Appendix B, NASA TM X-64627 for details.

3.1.2 The design steady-state values of the orbital neutral atmospheric gas properties shall be calculated using a value of 230 for the mean 10.7 cm solar flux and a geomagnetic index (a_p) of 20.3 with a local time of day of 0900 hr as inputs to the Jacchia 1970 Model Atmosphere.

3.1.3 The design short-time extreme values of the atmospheric gas properties shall be calculated using a value of 230 for the mean 10.7 cm solar flux and a geomagnetic index (a_p) value of 400, and a local time of day of 1400 hr as input to the Jacchia 1970 Model Atmosphere. These orbital neutral atmospheric gas property values represent an estimate of the conditions that may occur for a short period of time (12 to 36 hrs) during an extremely large magnetic storm.

3.1.4 Exosphere (37,000 km Geosynchronous Orbital Altitude) - The data given in Section 2.2.2 of NASA TM X-64627 shall be used.

4.0 CHARGED PARTICLES

The electron density values and data in Section 2.3 of NASA TM X-64627 shall be used.

5.0 RADIATION

In addition to the following, use Section 2.4 of NASA TM X-64627. The Solar Electric Propulsion Stage shall be designed to provide necessary protection to insure the safe dosage limits of the equipment are not exceeded.

5.1 Galactic Cosmic Radiation - Galactic cosmic radiation consists of low intensity, extremely high energy charged particles. These particles, about 85 percent protons, 13 percent alphas, and the remainder heavier nuclei, bombard the solar system from all directions. They have energies from 10^8 to 10^{19} electron volts (ev) per particle and are encounteres essentially everywhere in space. The intensity of this environment in "free-space," e.g., outside the influence of the earth's magnetic field, is relatively constant (.2 to .4 particles per squere centimeter per steradian per second) except during periods of enhanced solar activity when the fluxes of cosmic rays have been observed to decrease due to an increase in the strength of the interplanetary magnetic field which acts as a shield to incoming particles. Near the earth, cosmic rays are similarly influenced by the earth's magnetic field resulting in a spatial variation in their intensity. The extreme of the galactic cosmic ray environment is at sunspot minimum. The environment is constant and may be scaled down to 24 hours. See Section 2.4.1 of NASA TM X-64627 for additional data on this subject.

Estimates of the daily cosmic ray dose for the various orbits are shown in Table 1. These should be considered in the SEPS studies.

Table 1. Galactic Cosmic Ray Dose (REM/Day)

	255 n.m. 55^{o} Incl.	200 n.m. Polar	Geo-synchronous
Solar Maximum	0.005	0.008	0.024
Solar Minimum	0.008	0.013	0.036

5.2 Trapped Radiation - The trapped radiation environment will be taken from most recent data of NASA SP-3024 (currently in six volumes) or from the TRECO computer code available from the National Space Science Data Center, NASA/Goddard Space Flight Center, and merged with trajectory information to find particle fluxes and spectra. The fluxes and spectra will be converted to dose by data and/or computer codes provided by MSFC/S&E-SSL-NR (see Section 2.4.2 of NASA TM X-64627).

5.2.1 Near-Earth Environment - The radiation belts trapped near the earth are approximately azimuthally symmetric, with the exception of the South Atlantic Anomaly where the radiation belts reach their lowest altitude. The naturally occurring trapped radiation environment in the anomaly region remains fairly constant with time although it does fluctuate with solar activity. Electrons will be encountered at low altitudes in the anomaly region as well as in the auroral zones.

5.2.2 Synchronous Orbit Altitude Environment - The trapped proton environment at synchronous orbit altitude is of no direct biological significance, but may cause deterioration of material surfaces over long exposure times. The proton flux at this altitude is composed of only low energy protons (less than 4 Mev) and is on the order of 10^5 protons/cm^2-sec. The trapped electron environment at synchronous altitude is characterized by variations in particle intensity of several orders of magnitude over periods as short as a few hours. However, for extended synchronous altitude missions, a local time averaged environment can be used. See Section 2.4.2.2 of NASA TM X-64627 for additional data.

5.3 Solar Particle Events - Solar particle events are the emission of charged particles from distrubed regions on the sun during solar flares. They are composed of energetic protons and alpha particles that occur sporadically and last for several days. The free-space particle event model to be used for the SEPS orbital studies is given in Section 2.4.3.1 of NASA TM X-64627.

6.0 GEOMAGNETIC ENVIRONMENT

The values given in Section 2.6 of NASA TM X-64627 shall be used.

7.0 METEOROIDS

The SEP Stage shall be designed for at least a 0.95 probability of no puncture during the maximum total time in orbit using the meteoroid model defined in Section 2.5.1 of NASA TM X-64627.

7.1 Meteoroid Impact - The SEP Stage shall provide protection against loss of functional capability of selected critical items when subjected to the meteoroid flux model as defined in NASA TM X-64627. The probability of no penetration shall be assessed on each item dependent upon functional criticality.

8.0 ASTRODYNAMIC CONSTANTS

The values given in Section 1.6 and 2.7 of NASA TM X-64627 shall be used.

9.0 INTERPLANETARY SPACE

Interplanetary space is defined as the region from the sun to the outer limits of the solar system, exclusive of those spheres under the influence of the individual planetary systems.

9.1 Gas Properties - The sun is coupled to the environments of the planets through the interplanetary medium. The sun's varying input to this medium and its impact on solar wind particle radiation and plasma flow is of primary concern. For design purposes, the following gas properties should be employed.

9.1.1 Kinetic Gas Temperature

Approximately 2×10^5 °K

9.1.2 Gas Pressure

Approximately 10^{-10} dynes/cm^2

9.1.3 Density

Approximately 10^{-23} gm/cm^3

9.1.4 Composition

The composition of interplanetary space is primarily hydrogen, protons, helium, and alpha particles.

9.2 Radiation Environment - The information given in Section 1.3 of NASA TM X-64627 shall be used.

9.3 Meteoroids, Asteroids, Comets - The values given in Section 1.4 of NASA TM X-64627 shall be used.

9.4 Geomagnetic Environment - The values given in Section 1.5 of NASA TM X-64627 shall be used.

REFERENCES

1. Smith, R. E. (editor), "Space and Planetary Environment Criteria Guidelines for Use in Space Vehicle Development (1971 Revision), NASA TM X-64627, November 15, 1971.

2. Daniels, G. E. (editor), "Terrestrial Environment (Climatic) Criteria Guidelines for Use in Aerospace Vehicle Development (1973 Revision), NASA TM X-64757, July 5, 1973.

3. North American Rockwell, Space Division, "Expected Environments for the Solar Electric Propulsion Stage," SD72-SA, 0129, Downey, California, 1972.

APPROVAL

NATURAL DESIGN REQUIREMENTS FOR THE SOLAR ELECTRIC PROPULSION STAGE

by Lewis E. Andrews

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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